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Mark IVA DSN Receiver-Exciter and Transmitter Subsystems

M. R. Wick

TDA Engineering Office

This article describes the present configuration of the Mark IVA DSN Receiver-Exciter and Transmitter Subsystems. Functional requirements and key characteristics are given to show the differences in the capabilities required by the Networks Consolidation task for combined High Earth Orbiter and Deep Space Network tracking support.

I. Introduction

The purpose of this article is to describe the Receiver-Exciter and Transmitter Subsystems in the Mark IVA configuration as recently implemented at the Goldstone, Canberra, and Madrid Deep Space Tracking Stations. Mission requirements contributing to the changing configuration include Voyager, Magellan (Venus Radar Mapper), Venus-Balloon/Pathfinder support of High Earth Orbiters (HEO) including ICE, AMPTE, Shuttle, and Ulysses.

The Receiver-Exciter Subsystem and Transmitter Subsystem at the 64-meter and 34-meter standard (STD) receive-transmit antennas have been modified for central control. Venus-Balloon and Pathfinder required the addition of an L-band (1 GHz) downlink capability at the 64-meter antennas. A high power 400-kW Transmit capability was also added to the 64-meter antennas to support Voyager Uranus and ICE missions, and the 34-meter standard (STD) subnet was modified to provide S-band (2 GHz) uplink and downlink coverage of the HEO frequency band. A Block III Receive channel was installed in the new 34-meter High Efficiency Antennas.

II. Functional Description

A. Receiver-Exciter Subsystem

The Receiver-Exciter Subsystem is composed of three groups of equipment: the Closed Loop Group, the Open Loop Group, and the RF Monitor Group.

The Closed Loop phase tracking reception of spacecraft microwave signals provides telemetry and radiometrics. Table 1 gives the present Closed Loop configuration set at each station in the DSN. The received signals are demodulated for telemetry processing; spacecraft doppler residuals are extracted; and Intermediate Frequency (IF) signals containing ranging code are separated for further processing of tracking information.

The Open Loop Group provides radio path effects on the spacecraft signal and observations of extra-galactic radio source noise spectra for Radio Science and Very Long Baseline Interferometry purposes.

The RF Monitor Group provides spectral measurements, measurements of the receive channel system temperature, and spacecraft signal level. Key characteristics of the Receiver-Exciter Subsystem are as follows:

- (1) L-band (1 GHz), S-band (2 GHz), and X-band (8.5 GHz) reception of deep space spacecraft signals.
- (2) S-band reception of high Earth orbiter spacecraft signals.
- (3) S-band (2 GHz) and X-band (7 GHz) uplink with command and range modulations.
- (4) Coherent two-way doppler and range, S-band and X-band.
- (5) Baseband telemetry demodulation.
- (6) Generation of X-band and S-band microwave test signals.
- (7) Open-loop down conversion of X-band and S-band radio science occultation signals.
- (8) Open-loop down conversion of X-band and S-band VLBI signals.
- (9) High-resolution spectral signal indication.
- (10) Precision measurement of system temperature and carrier signal power.
- (11) Centralized monitor and control.
- (12) Predicts-driven automatic tuning of receiver and exciter frequencies (deferred to 1988).

The Mark IVA configuration of the Receiver-Exciter Groups is described below.

1. Closed Loop Receiver Group. The Block IV Receiver-Exciter (Fig. 1) in the 64-meter antenna contains two receive channels each capable of L-band (1 GHz), S-band (2 GHz) or X-band (8.5 GHz) reception and an S-band exciter which generates the uplink carrier for transmission to the spacecraft after being amplified by either a low-power 20-kW or high power 400-kW transmitter. The uplink frequency is computer controlled, for phase-continuous frequency tuning. The Block IV Receiver-Exciter has been modified for central control from the Signal Processing Center (SPC) at Goldstone, Canberra, and Madrid. An L-band to S-band upconverter was also installed in the 64-meter antennas as part of the Block IV Receiver-Exciter to support the Venus-Balloon/Pathfinder experiment. An L-band horn and low noise amplifier (FET) was added to the microwave equipment (Ref. 1), and an L-band noise diode added to the Precision Power Monitor for L-band System Temperature Measurements (Fig. 8).

The Block III Receiver-Exciter at the 34-meter STD antennas (Fig. 2) contains two receive channels each capable of S-band or X-band reception and generates an S-band uplink carrier which drives a 20-kW low-power transmitter. The uplink frequency is computer-controlled for phase-continuous tuning. This 34-meter STD antenna Block III Receiver-Exciter has been modified to cover both the DSN and HEO uplink and downlink frequency bands (Table 2), and is capable of reception over the DSN X-band frequency range. It has also been modified for central control from the SPC.

One channel of a Block III Receiver has been installed at the new 34-meter HEF antennas at DSS 15 and DSS 45 (Fig. 3). The modification is similar to that at the 34-meter STD antenna except that the tuning range is limited to the DSN frequencies at both S-band and X-band (see Table 2). At present, these stations are single channel downlink, receive only.

2. Open Loop Receiver Group. The Open Loop Receiver Group performs open loop frequency down conversion for DSN Radio Science and Very Long Baseline Interferometry (VLBI) purposes. Four channels of S-band (2 GHz) and X-band (8.5 GHz) signals are received (2-channel S-band, LCP and RCP, and 2-channel X-band, LCP and RCP) at the 64-meter antennas. These signals are down-converted to video frequencies for processing by the Radio Science/VLBI Spectrum Processing Subsystem.

The Radio Science/VLBI Open Loop Receiver Group (Fig. 4) uses a different type of down conversion and data processing methodology than that of the Closed Loop Receivers. Down conversion is accomplished so as to preserve the amplitude and phase variations for analysis of the effects of both the radio source and radio path. Within this Open Loop Receiver Group are two similar yet quite different receivers: the Radio Science Receiver and VLBI Receiver. The Radio Science Receiver is used to observe radio source and path effects of a spacecraft generated "line spectra" carrier, whereas the VLBI Receiver is used to observe both the characteristics of "line spectra" and Extra Galactic Radio Sources noise spectra for Radio Science, spacecraft navigation, and Time Sync of the DSN tracking network.

The Radio Science Open Loop Receiver (Fig. 5) has a different type of IF to video down conversion than the VLBI Open Loop Receiver; however, it is similar in that the image-noise spectrum is rejected, thus preserving the input signal SNR. Figure 5 shows the present configuration implemented at the 64-meter antennas for the Voyager-Uranus encounter. The IF-VF converter uses crystal bandpass filters with selectable BWs to reject image noise. A programmable local oscillator is used to correct for the doppler shift effect of the

received carrier signal to maintain centering of the received signal within the narrow, fixed bandwidth of the crystal filter. This signal is then further down-converted to the video band for recording.

Table 2 lists the open loop frequency tuning ranges. Frequency tuning, filter selection, and signal attenuation of the receiver are planned to be remotely controllable from the Radio Science/VLBI Spectrum Processor Subsystem. Presently, only the frequency is remotely controlled.

The VLBI IF to video converters use single-sideband (SSB) methodology for image-noise rejection. Tunable oscillators provide frequency flexibility in the channel selection. This permits variable data channel bandwidths by selectable low-pass filtering of the video band, i.e., the capability of down converting a segment of the BW at any frequency over a broad RF spectrum.

The VLBI IF to video down converters are of two types: a Narrowband Channel Bandwidth (NCB) type (BLK I) (Fig. 6) with channel BW in the kHz range, and a Wide Channel Bandwidth (WCB) type (BLK 0 and BLK II) (Fig. 7) with BW in the MHz range.

NCB IF to video down conversion is used for Universal Time 1 (UT1), Polar Motion (PM), Clock Sync, and DOR (Differential Downlink One Way Range) applications. The WCB IF to video down conversion is used for Radio Source Catalog Maintenance by observing the continuous noise spectrum of Extra Galactic Radio Sources (EGRS) using extremely large spanned BW (100 to 400 MHz at X-band).

The VLBI receiver furnishes two video signals in quadrature, 0 and -90 degrees, to the Spectrum Processor (DSP). The DSP uses digital techniques to generate a second -90-degree phase lag and summation needed to accomplish the image rejection (Ref. 3). Within the span bandwidth of 100 MHz, eight X-band and four S-band channels, each generated by one of 12 digitally controlled local oscillators, are used in the down conversion. These oscillators are operated continuously uninterrupted to preserve the reference phase.

3. RF Monitor Group. The RF Monitor Group consists of a Precision Power Monitor (PPM) for system temperature and signal level measurement and a Spectral Signal Indicator (SSI) which generates digital spectral data for display.

The PPM measures antenna system noise temperature using a Noise Adding Radiometer (NAR) and measures received carrier-signal power level with a Signal Level Estimator (SLE). Figure 8 shows the Goldstone and Canberra 64-meter antenna installation of the PPM. The PPM input is from the Closed

Loop Receiver 2nd IF frequency (50-MHz Block III Receiver, 55-MHz Block IV Receivers) prior to the gain control (AGC). The Canberra installation differs slightly because of the collocation of DSS 42; however, both the Goldstone and the Canberra antennas have a full complement of noise diodes for all input channels.

Signal level measurement is based on the results of the system temperature measurement conducted simultaneously on the same antenna for the same signal stream. Measured noise power from a radio star is used for antenna pointing calibrations. The measured carrier signal level is also a radio science data type and is a reference for calibrating test signals, command modulation indices, receiver AGC curves, and an indicator of telemetry system performance. PPM capability has been implemented at the Goldstone and Canberra 64-meter and 34-meter stations for Voyager-Uranus Encounter; a PPM will be installed at Madrid to support the Galileo and Magellan missions. The PPM is centrally controlled from the Monitor and Control Subsystem at the SPC.

Signal-spectrum measurements are performed by a Spectral Signal Indicator (SSI) which translates a video band signal into a frequency spectrum and generates digital spectral data for display at the Signal Processing Center and also for transmission to JPL. Principal uses of the SSI include detection and monitoring of spacecraft frequency variations during a radio science experiment, and an indication of signal presence and spectral properties during a test. The SSI has not been modified for centralized control.

4. Transmitter Subsystem. The Transmitter Subsystem is composed of three groups of equipment (Fig. 9). A low-power 20-kW S-band transmitter and a high-power 400-kW S-band (2 GHz) transmitter at each 64-meter antenna, and a low-power 20-kW S-band transmitter at each 34-meter standard antenna. Key characteristics of the Transmitter Subsystem are as follows:

- (1) S-band 20-kW transmit capability at the 34-meter HEF antennas covering the DSN and HEO tuning range.
- (2) S-band 20-kW transmit capability at the 64-meter antennas covering the DSN tuning range.
- (3) S-band 400-kW transmit capability at the 64-meter antennas covering the DSN tuning range and 2090.6 MHz at reduced power for the ICE mission.
- (4) Centralized monitor and control.
- (5) Interlock protection circuits for equipment and personnel.

The Transmitter Subsystem amplifies drive signals from the Block III or Block IV Receiver-Exciter Subsystem exciter and illuminates the antenna via the Microwave Subsystem feed. The 20-kW and 400-kW transmitters at the 64-meter antenna are operated simultaneously.

The high-power transmitters are installed at all three 64-meter antennas to provide emergency commanding of a deep space mission, such as Voyager, in case the spacecraft must use its low-gain antenna for communications with Earth. The Canberra high-power transmitter was operated at 60 kW to ensure low-noise telemetry performance at the Voyager mission Uranus encounter, operating in a two-way communications mode. The high-power transmitter was designed and used for coverage of the ICE uplink frequency (2090.6 MHz) for similar purposes.

The 2110 to 2120-MHz transmit range is used by the deep space missions, whereas the High Earth Orbiter (HEO) missions use the 2025 to 2120-MHz range. As such, the 34-meter standard antennas can support all HEO and DSN frequencies up to 20 kW. The 64-meter antenna supports DSN frequencies only in S-band with the exception of the ICE frequency.

Both the low-power and high-power transmitters received modifications for increased reliability including the capability for centralized control for reduced manual operations. The high-power transmitter central control modifications have been completed; the low-power transmitters have been modified for monitor capability with control capability deferred until 1986. Figure 10 shows the functional elements of each transmitter.

III. Modifications Planned (1986–1988)

At the Madrid complex, a 34-meter HEF antenna will be built to support Galileo and Magellan; construction is to be completed in mid-1986. The Canberra and Madrid HEF antennas, DSS 45 and DSS 65, will receive the new X-band exciter and X-band 20-kW transmitter (Ref. 2) planned for operational use in 1987.

Initially, these stations will be capable of X-band telemetry, Radio Science, and VLBI. Radiometric capability is to be added for the Magellan mission. The new X-band transmitter will be phase-stabilized with a phase control loop implemented in the exciter. A sample of the transmitter output is fed back to the exciter phase correction loop to minimize the uplink transmitted signal phase variations to less than 5 parts in 10^{15} as it leaves the transmitter.

Also, as part of the X-band uplink modification, the Radio Science Open Loop Receiver will be modified for tuning at the second local oscillator frequency, which improves stability and significantly reduces the noise present with the higher local oscillator frequency. The new Radio Science/ VLBI fixed first local oscillator down converter provides an output IF in the range 200 MHz to 400 MHz. Both the 64-meter and 34-meter HEF antennas will have the new down converter. The IF selector switch selects either antennas as the signal source.

The PPM will be installed at the Madrid complex for DSS 61, 63, and 65 antennas.

It is planned to incorporate a predict controlled digitally controlled oscillator and an automatic signal acquisition capability early in 1988 to support the high doppler rates of Magellan at Venus orbit.

References

1. Parsons, P., "Antenna Microwave Subsystem," *TDA Progress Report 42-79*, pp. 165-171, Jet Propulsion Laboratory, Pasadena, CA, Nov. 15, 1984.
2. Cormier, R., and Tesarek, T., "Development and Testing of a 20-kW X-Band Transmitter With High Phase Stability," *TDA Progress Report 42-79*, pp. 47-61, Jet Propulsion Laboratory, Pasadena, CA, Nov. 12, 1984.
3. Sosa, E. N., Sato, T., and Tyner, D. A., "Narrow Channel Bandwidth Receiver for VLBI," *TDA Progress Report 42-64*, pp. 18-29, Jet Propulsion Laboratory, Pasadena, CA, Aug. 15, 1981.

Table 1. Closed loop configuration set at DSN stations

Antenna ^a	Goldstone	Australia	Madrid
64-meter Transmit S-band Receive L, S, X-band	DSS 14	DSS 43	DSS 63
34-meter STD Transmit S-band Receive S, X-band	DSS 12	DSS 42	DSS 61
34-meter HEF Transmit X-band Receive S, X-band	DSS 15 ^b	DSS 45 ^c	DSS 65 ^c

^aS-band: 2 GHz; L-band: 1 GHz; X-band: 7 GHz uplink, 8.5 GHz downlink.
^bX-band transmit capability 1990.
^cX-band transmit capability 1987.

Table 2. Frequency tuning ranges

Antenna		Uplink, MHz	"Closed loop" downlink, MHz
64-m	DSSs 14, 43, 63	(LO PWR) 2110 - 2120 (HI PWR) 2090 - 2120	(L-band) 1663 - 1673 (S-band) 2200 - 2300 (X-band) 8400 - 8440
34-m STD	DSSs 12, 42, 61	(LO PWR) 2024 - 2120	(S-band) 2200 - 2300 (X-band) 8400 - 8440
34-m HEF	DSSs 15, 45, 65	(LO PWR) 7145 - 7190	(S-band) 2270 - 2300 (X-band) 8400 - 8440
Antenna		"Open loop-radio science/VLBI" downlink	
64-m	DSSs 14, 43, 64	2-channel RCP, LCP 2-channel RCP, LCP	(S-band) 2265 - 2305 (X-band) 8400 - 8500
34-m	DSSs 45, 65	1-channel 1-channel	(S-band) 2200 - 2300 (X-band) 8200 - 8600

LO PWR = 5 to 20 kW, HI PWR = 40 to 400 kW.
RCP, LCP = Right/Left Circular Polarization.

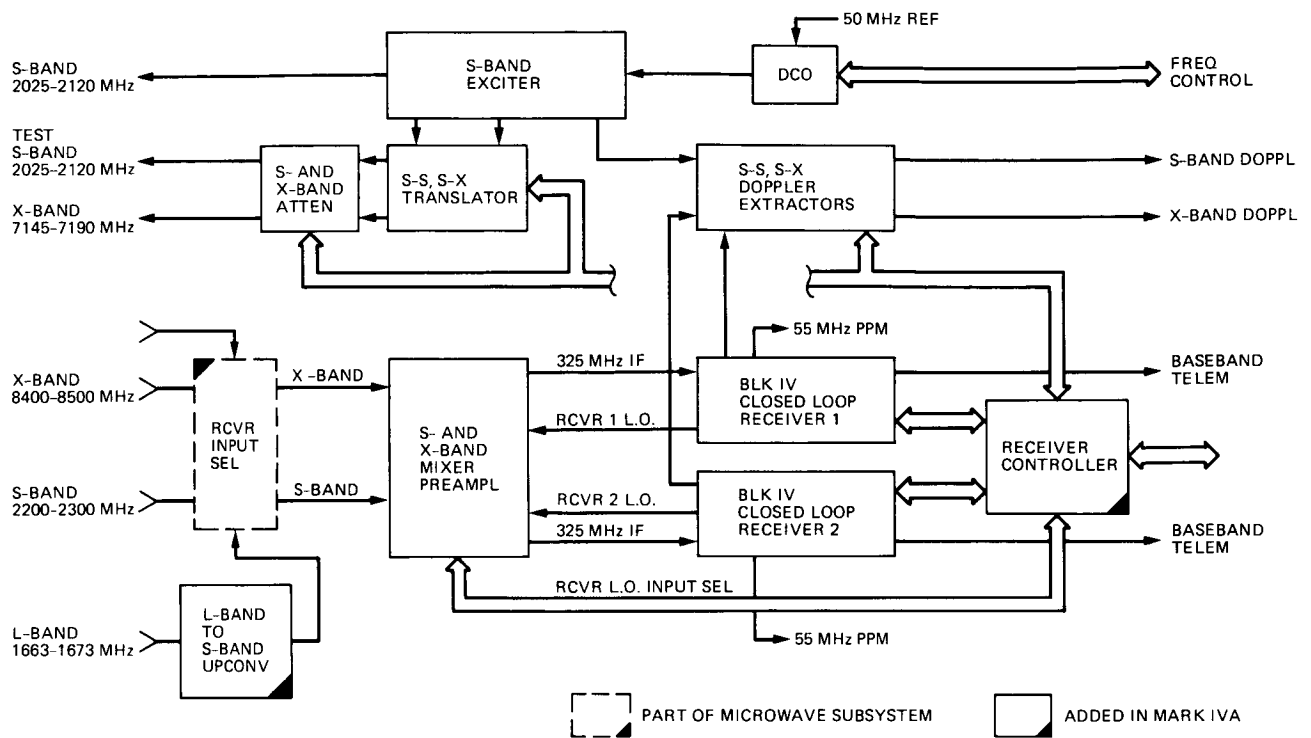


Fig. 1. Closed loop receiver group: 64-m block IV receiver-exciter

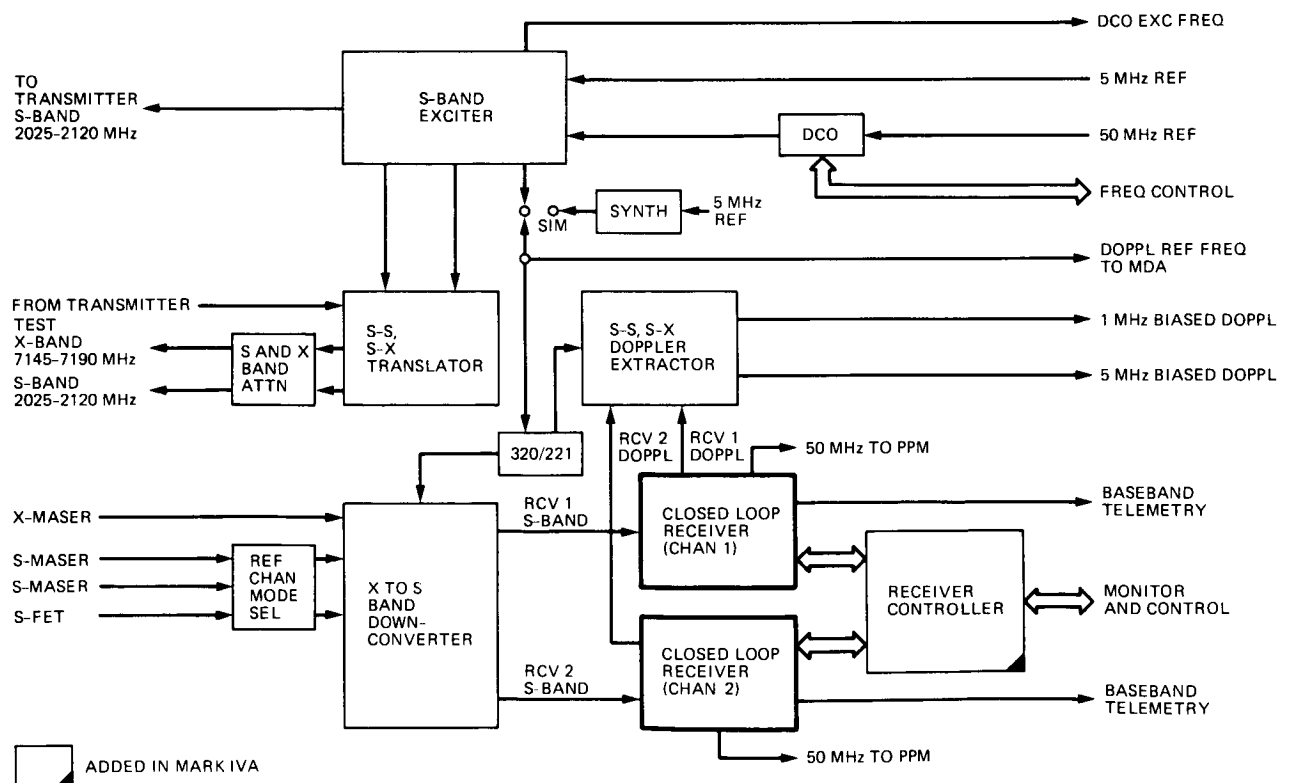


Fig. 2. Closed loop receiver group: 34-m standard block III receiver-exciter

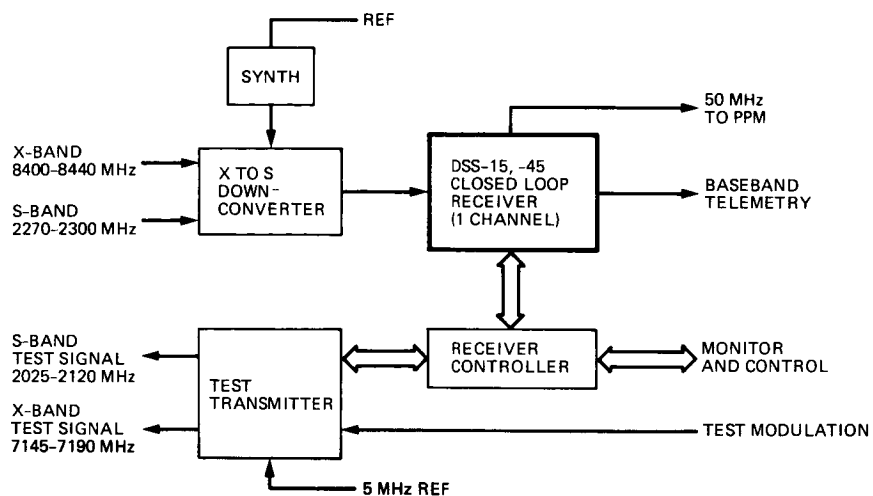


Fig. 3. Closed loop receiver group: 34-m HEF block III receiver

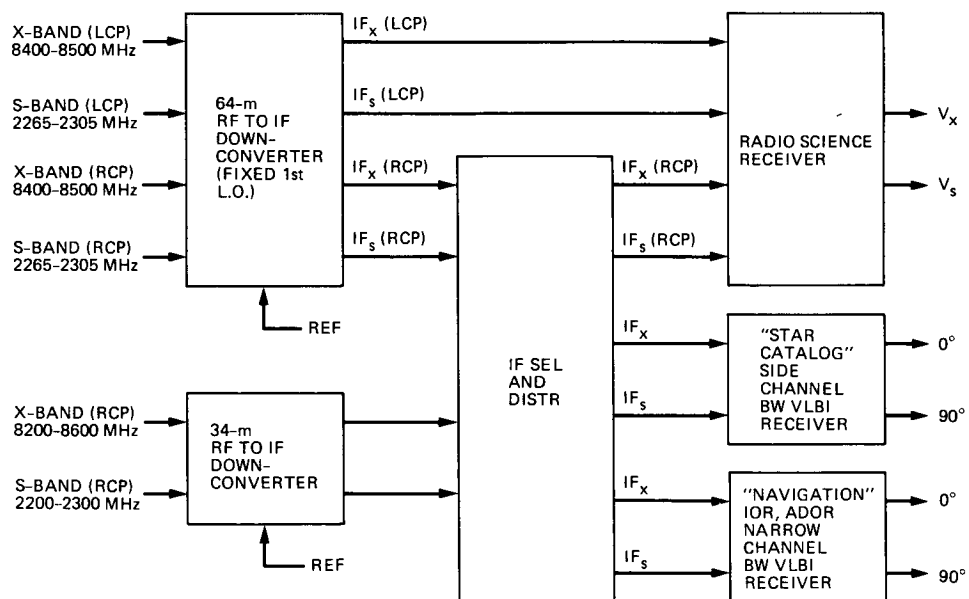


Fig. 4. Open loop receiver group

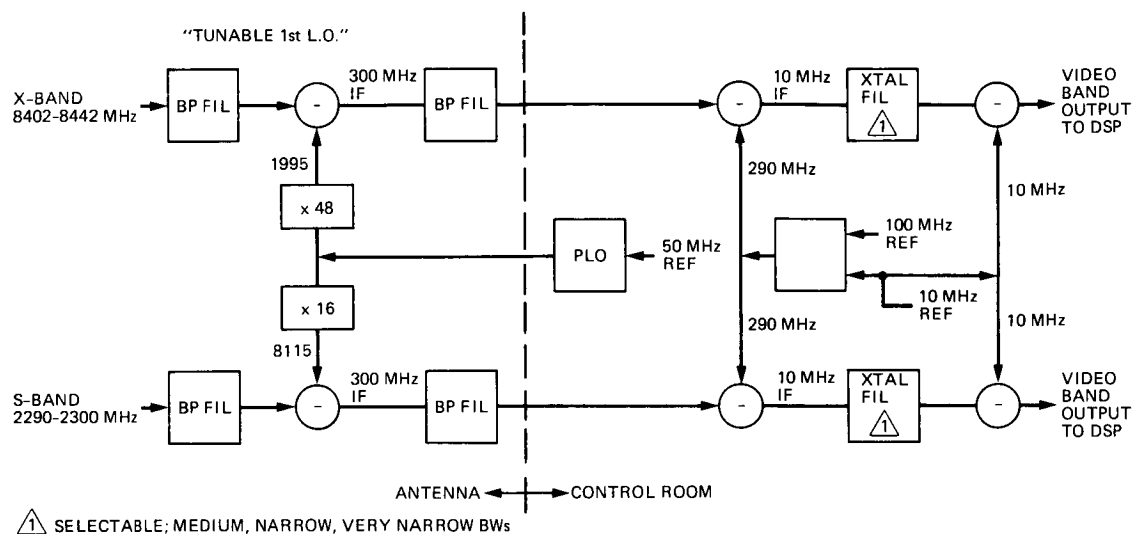


Fig. 5. Radio science receiver

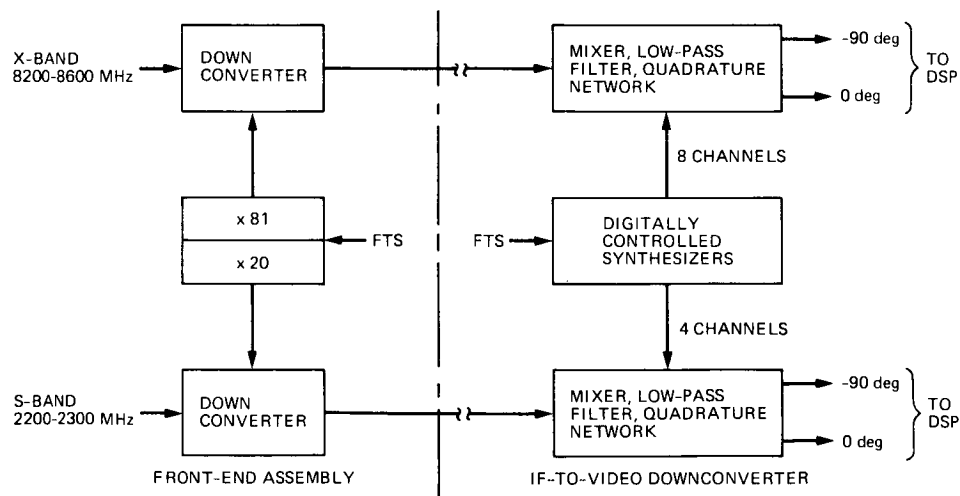


Fig. 6. Narrow channel BW VLBI receiver

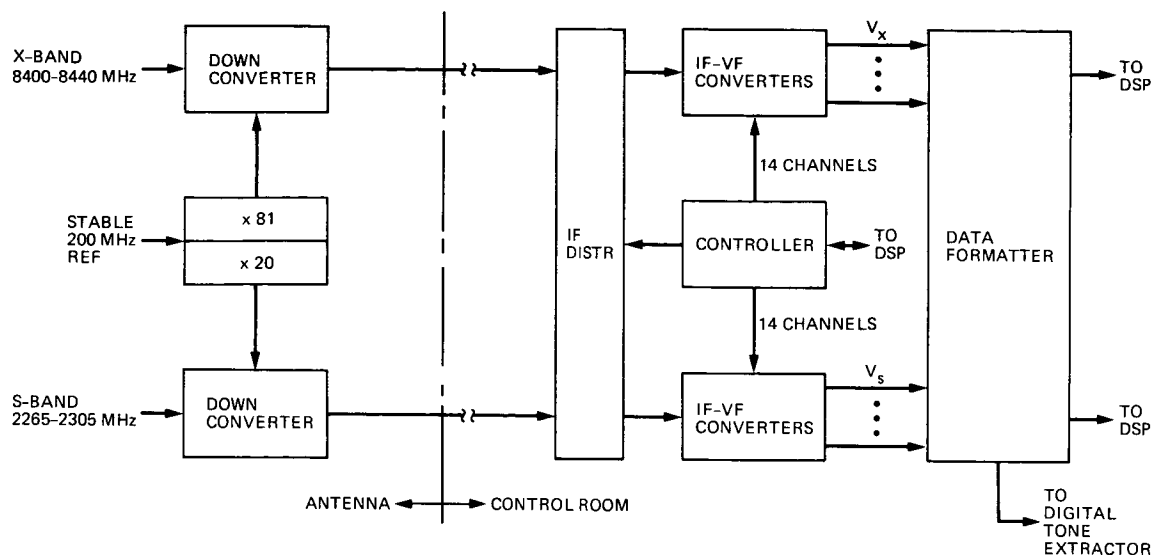


Fig. 7. Wide channel BW VLBI receiver

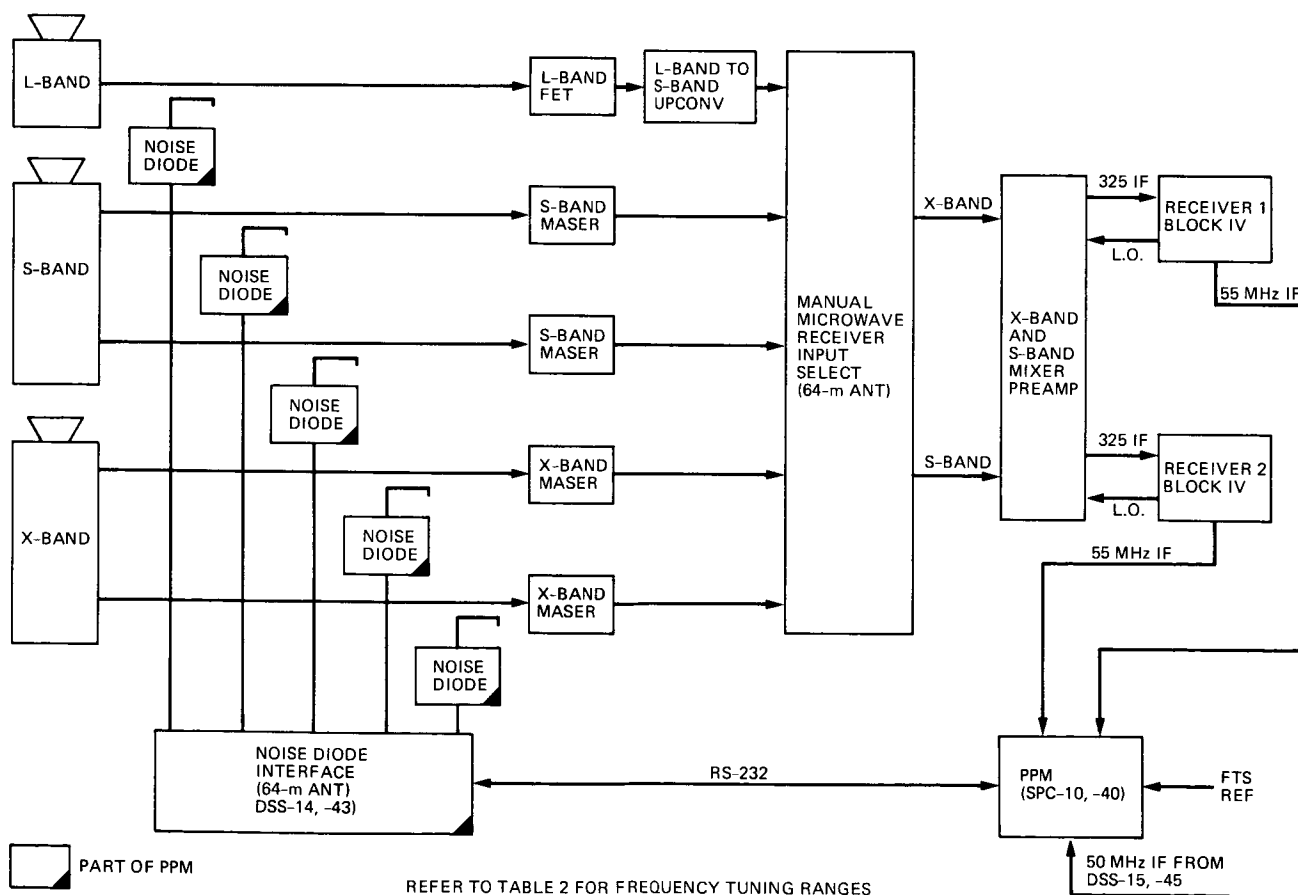


Fig. 8. RF monitor group: PPM

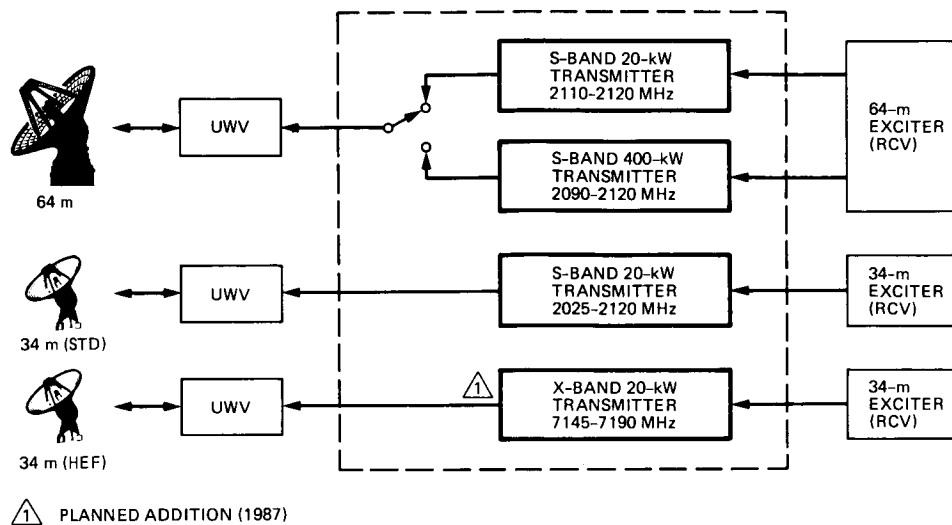


Fig. 9. Transmitter subsystem

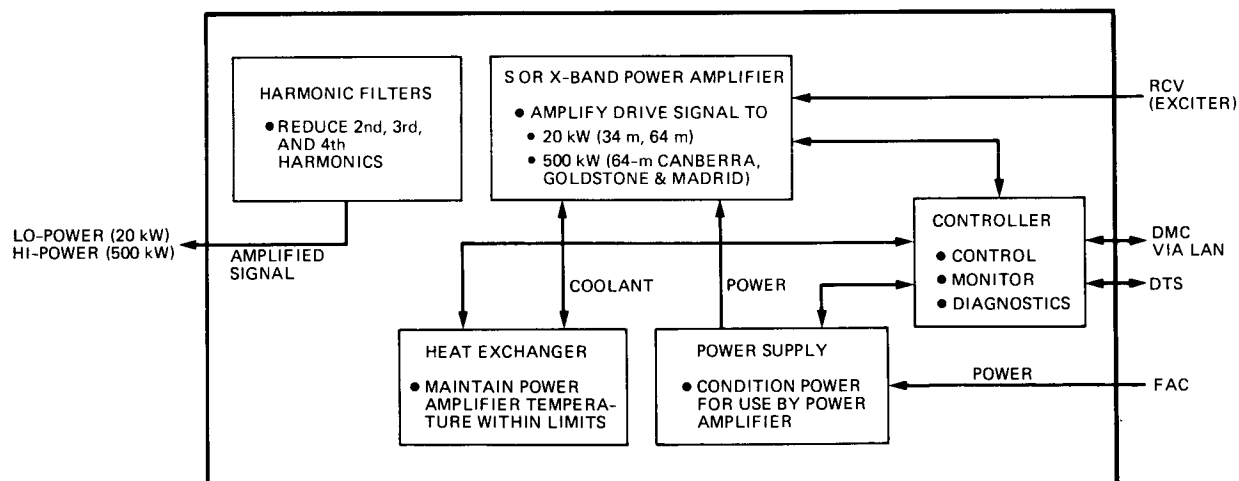


Fig. 10. Transmitter functional elements